# Swift X-ray Telescope Operations

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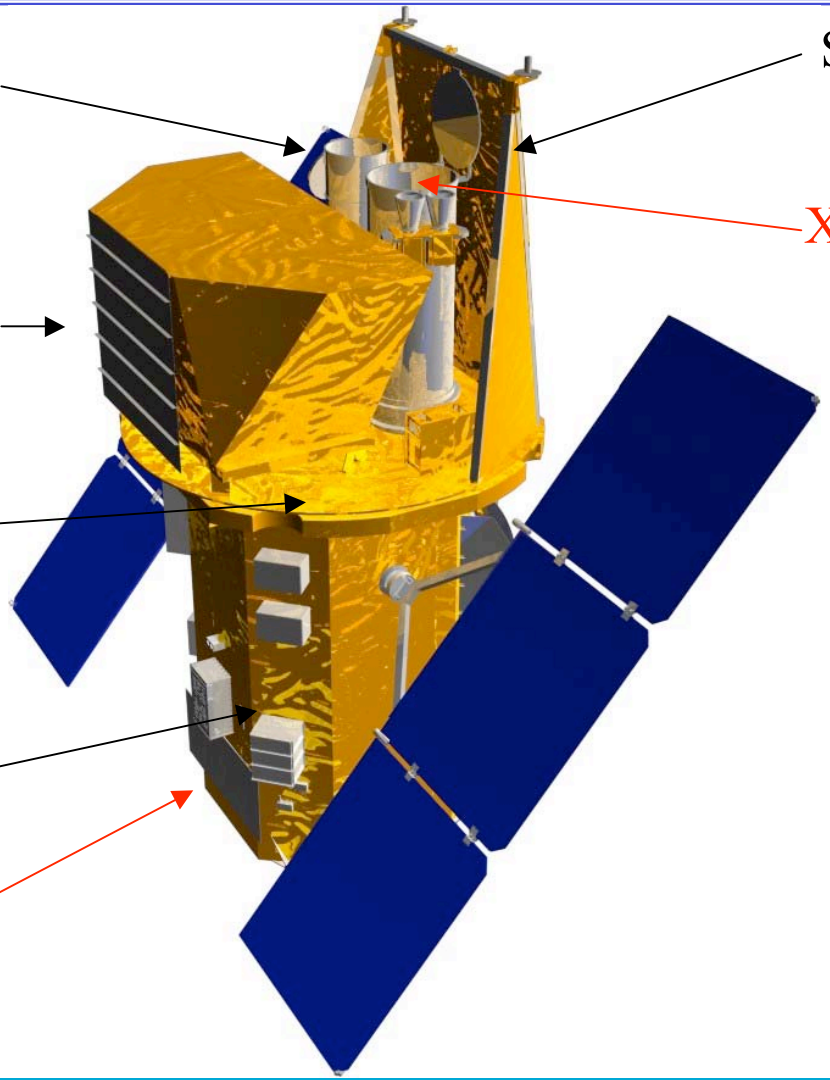
XRT Lead

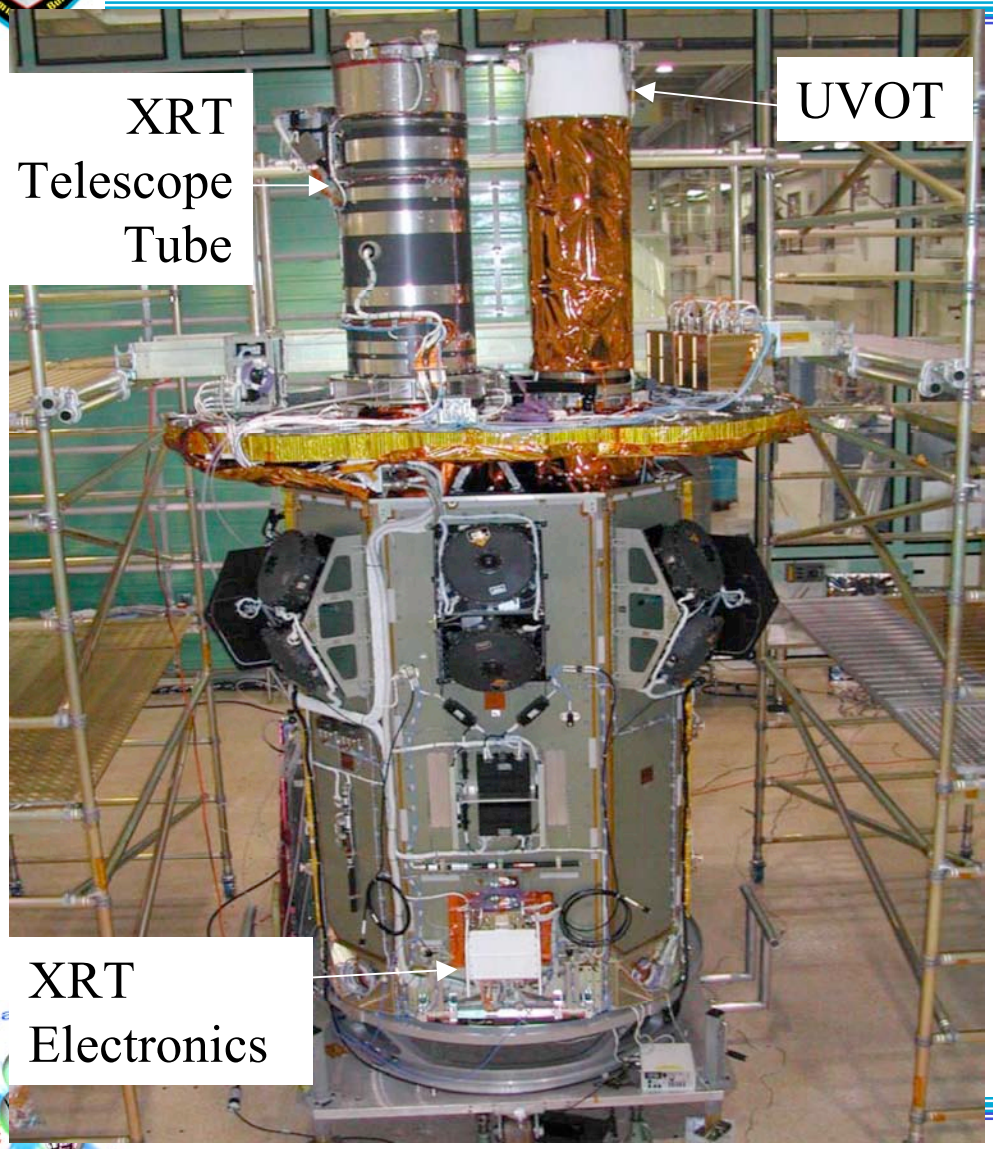
**University Partners:**
PSU UL OAB

**Calibration Partners:**
PSU / UL / OAB / MPE

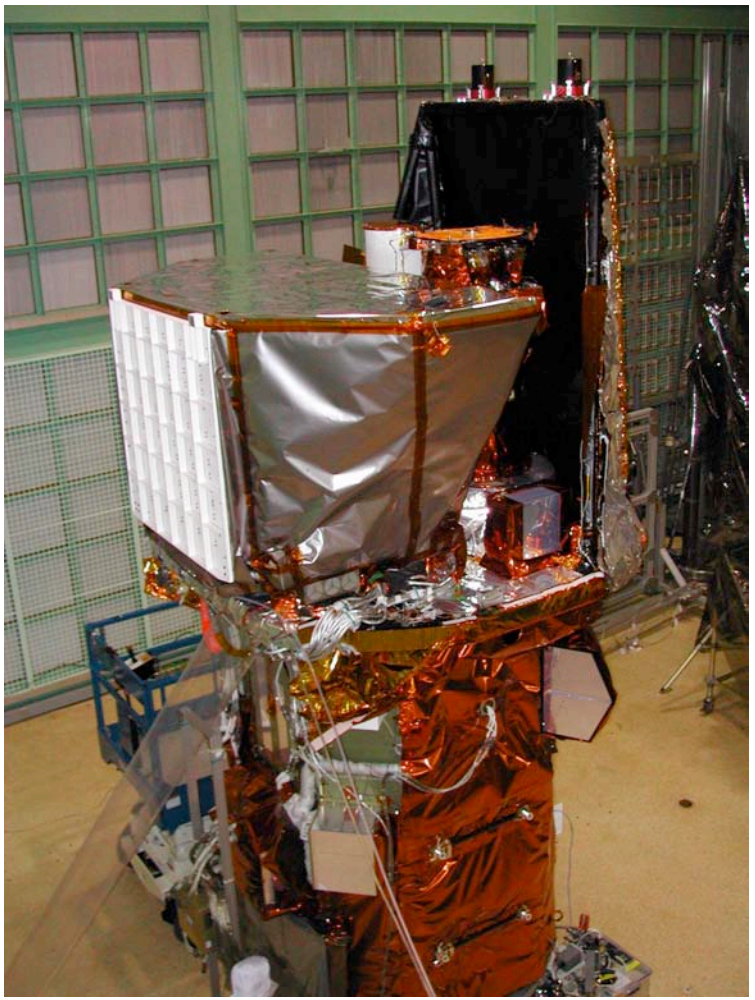
# Swift Artist's View



# The Swift Observatory




# The Swift Observatory



# XRT Science Goals

1) Rapid determination of GRB position
   (accuracy < 5'', transmit to ground < 100 s after burst)

2) X-ray spectroscopy
   - Determine Redshift from Emission Lines or Absorption Features in X-ray Spectrum
   - Determine physical conditions of ISM in vicinity of burst
     (energy resolution < 140 eV @ 6 keV at launch)

3) Burst/Afterglow Lightcurve
   - Monitor blast wave evolution
     (time resolution: 0.14 ms or 2.2 ms)

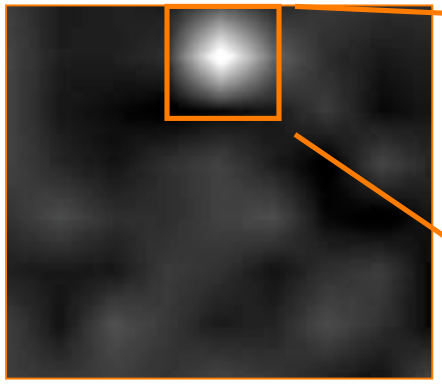
# XRT Instrument Characteristics

| | |
|---|---|
| Telescope | 3.5m Wolter I |
| Telescope PSF | 18 arcsec HPD @ 1.5 keV<br>22 arcsec HPD @ 8.1 keV |
| Detector | e2v CCD-22 |
| Detector Format | 600 x 602 pixels |
| Detector Readout Modes | Photon-counting, Imaging, & Timing |
| Field of View | 23.6 x 23.6 arcmin |
| Pixel Scale | 2.36 arcsec / pixel |
| Energy Range | 0.2 - 10 keV |
| Effective Area | 135 $cm^2$ @ 1.5 keV |
| Sensitivity | 2 x $10^{-14}$ ergs/$cm^2$/s in $10^4$ s |
| Position Accuracy | 2.5 arcseconds |
| Operation | Autonomous |

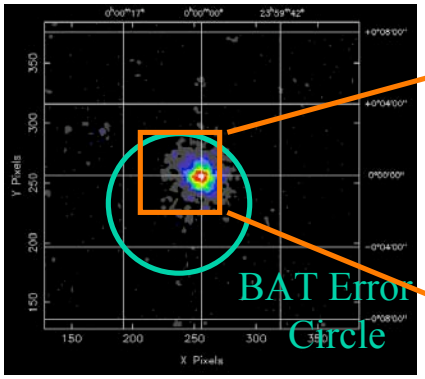
# Observing Scenario

1. Burst Alert Telescope triggers on GRB, calculates position on sky to < 4 arcmin
2. Spacecraft autonomously slews to GRB position in 20-75 s
3. X-ray Telescope determines position to ~3 arcseconds
4. UV/Optical Telescope images field, transmits finding chart to ground

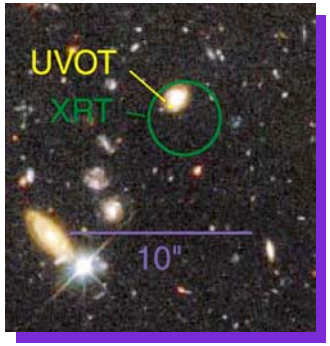
BAT Burst Image



XRT Image




UVOT Image




***T<10 sec***
***d_ ~ 4'***

***T < 100 sec***
***dθ ~ 3 arcseconds***

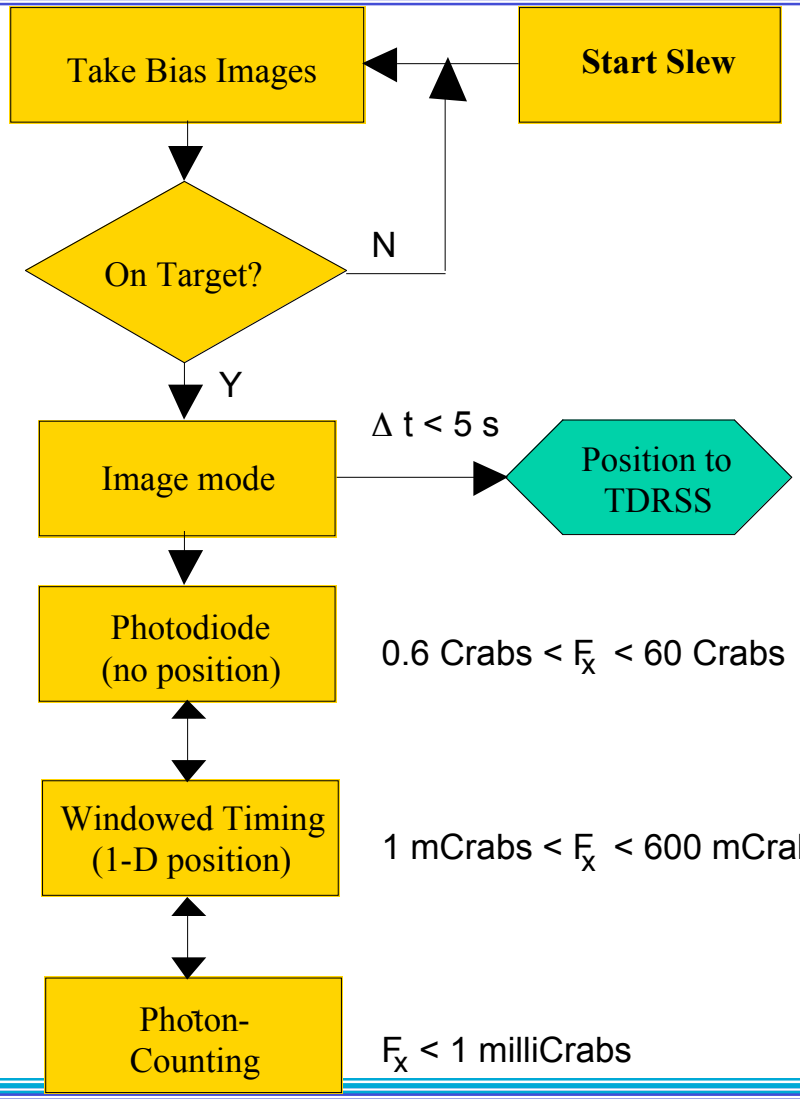
***T<300 sec***

# XRT Readout Modes

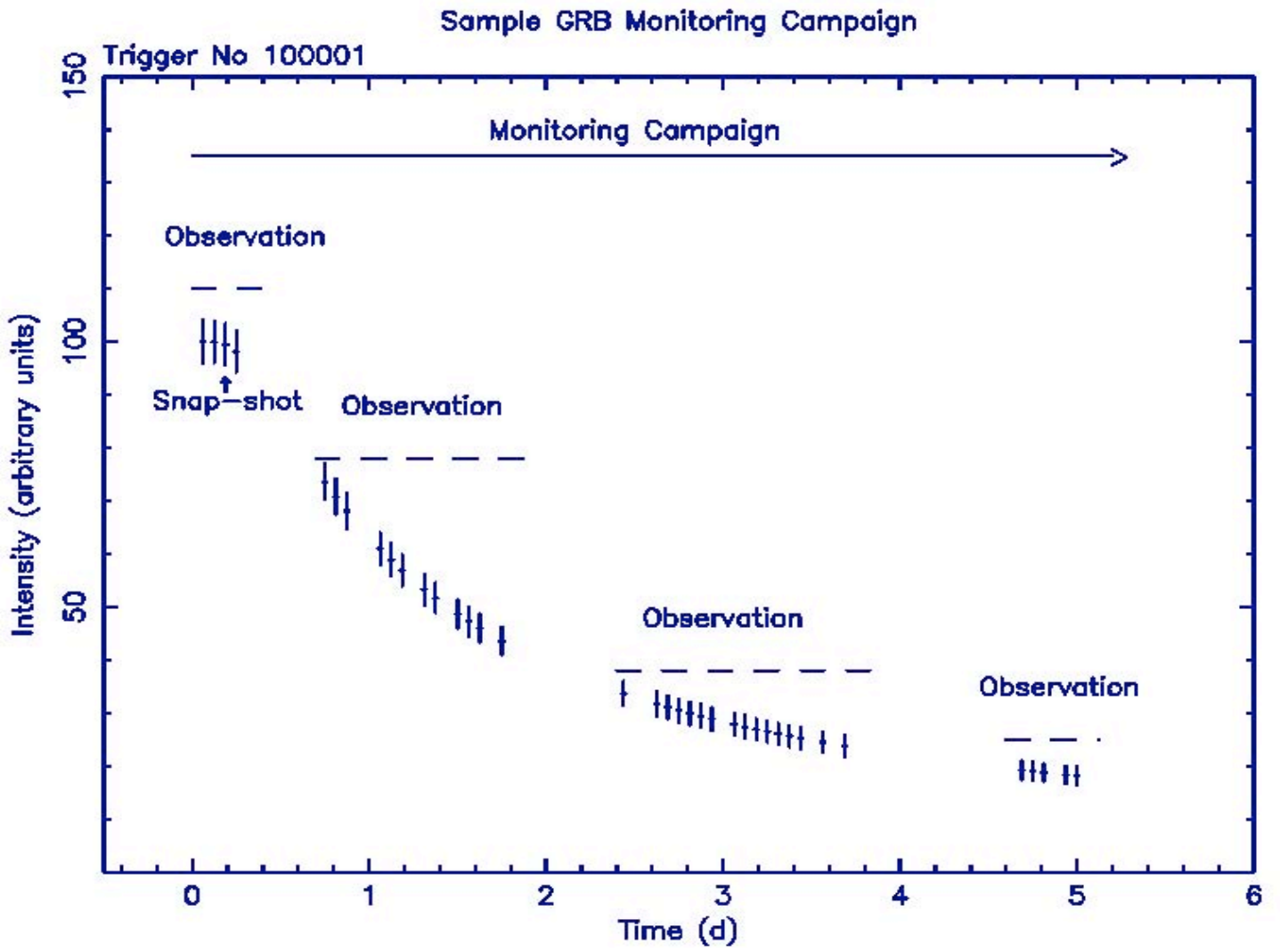
XRT must autonomously select readout modes suited to observations of GRBs and afterglows:

| Mode | Flux (Crabs) | Imaging | Spectroscopy | Timing | Bias | Data |
|---|---|---|---|---|---|---|
| Low Gain Imaging (centroid) | .025 - 37 | 2-D | None | 0.1 / 2.5 s | No bias subtraction | Centroid, Postage-stamp, thresholded image |
| Photodiode Timing | .05 – 60 | None | Full | 0.14 ms | Bias level subtraction | Events above threshold |
| Windowed Timing | .00005 - .15 | 1-D | Full | 2.2 ms | Bias row subtraction | Events above threshold |
| Photon-Counting | < 0.0001 | 2-D | Full | 2.5 s | Bias map subtraction | 3x3 neighborhoods above threshold |

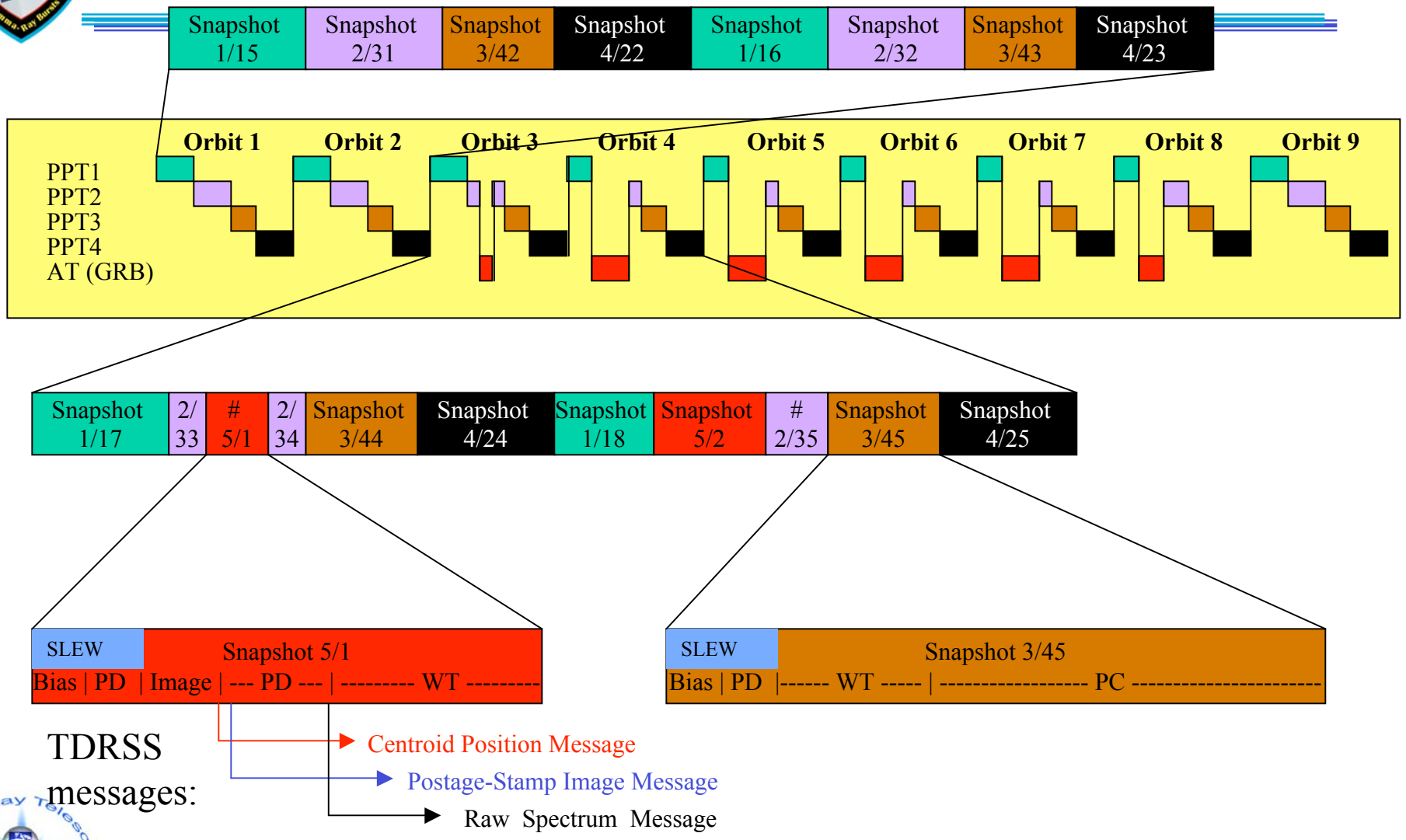
# XRT Autonomous Observing Sequence



# Swift GRB Monitoring



# Day in the Life of Swift XRT



# Typical XRT Observation Sequence

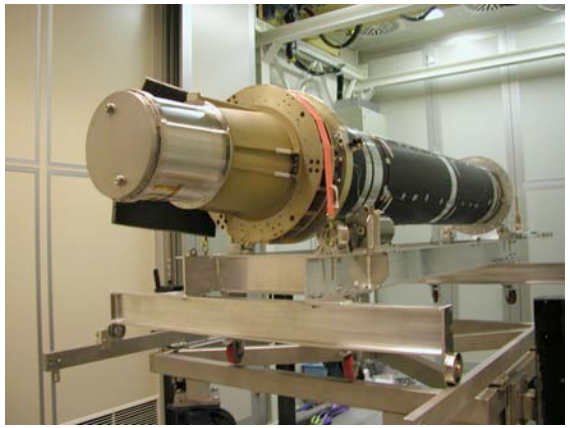
| | | | | | | |
|---|---|---|---|---|---|---|
| Flux (mCrabs) | 5000 | | 5000 | 3000 | 800 | 100 |
| Time (s) | 0 | 43 | 50 | 55 | 400 | 1000 |
| Activity | Slew | Settle | Centroid | Automated Observation | | Constraint Violation / Slew |
| Mode | Bias row, Bias map, (Raw frame), Photodiode | Photodiode mode | Image mode | Photodiode mode, 8s per 'frame' | Windowed Timing mode, 0.8 s per 'frame' | |
| Science Data Products | Bias map 600 x 602, (Raw Frame 635 x 602) | Photodiode events, 1 pixel 24' x 24' | Image pixels, 600 x 602 24' x 24' | Photodiode events, 1 pixel 24' x 24' | Windowed Timing events, 200 columns 8' x 24' | |

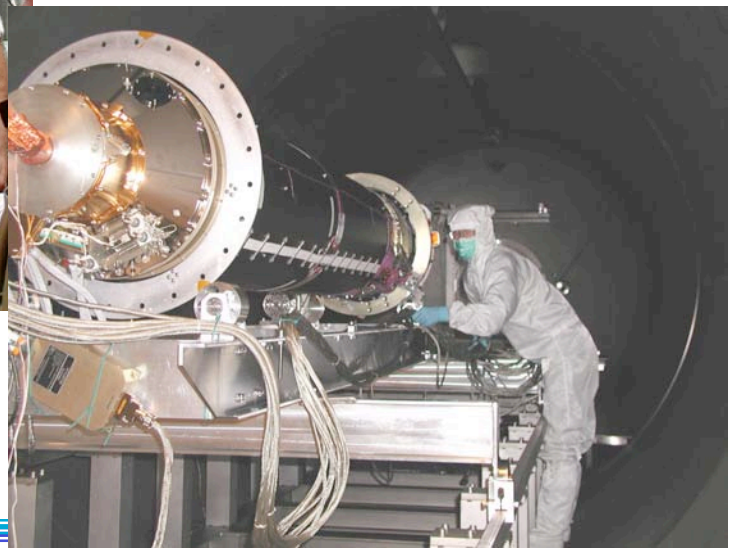
TDRSS Data Products

- Centroid Position →
- Postage-Stamp Image, 51 x 51 pixels, 2' x 2' →
- Raw Spectrum, 1024 channels, 0-10 keV →

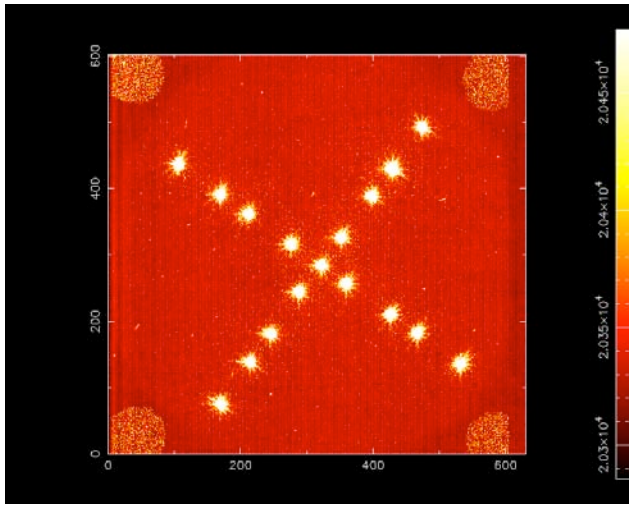
GCN

# XRT Calibration – Munich, September/October 2002

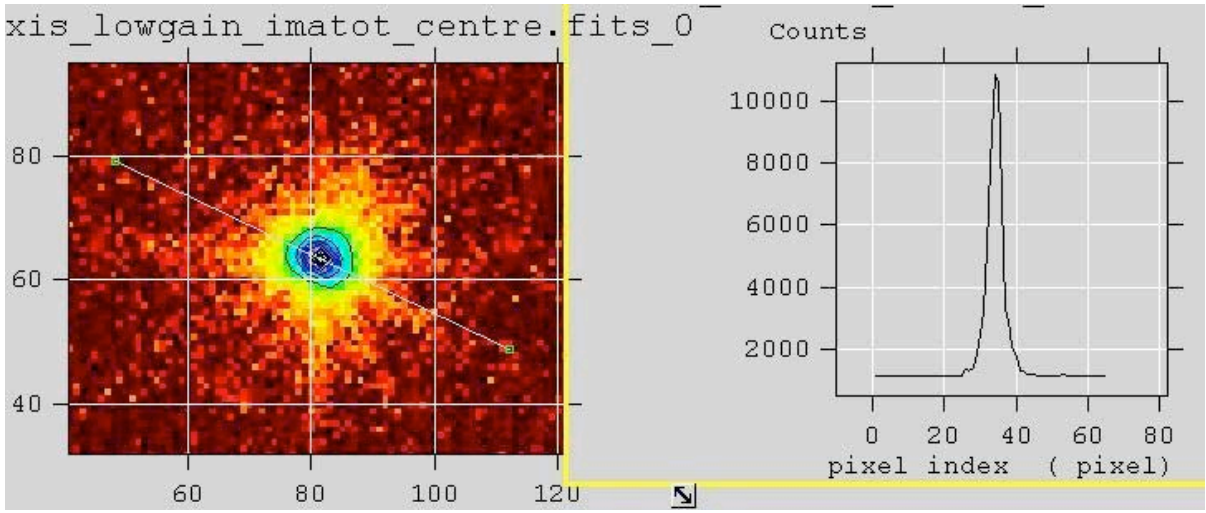




# XRT Angular Resolution

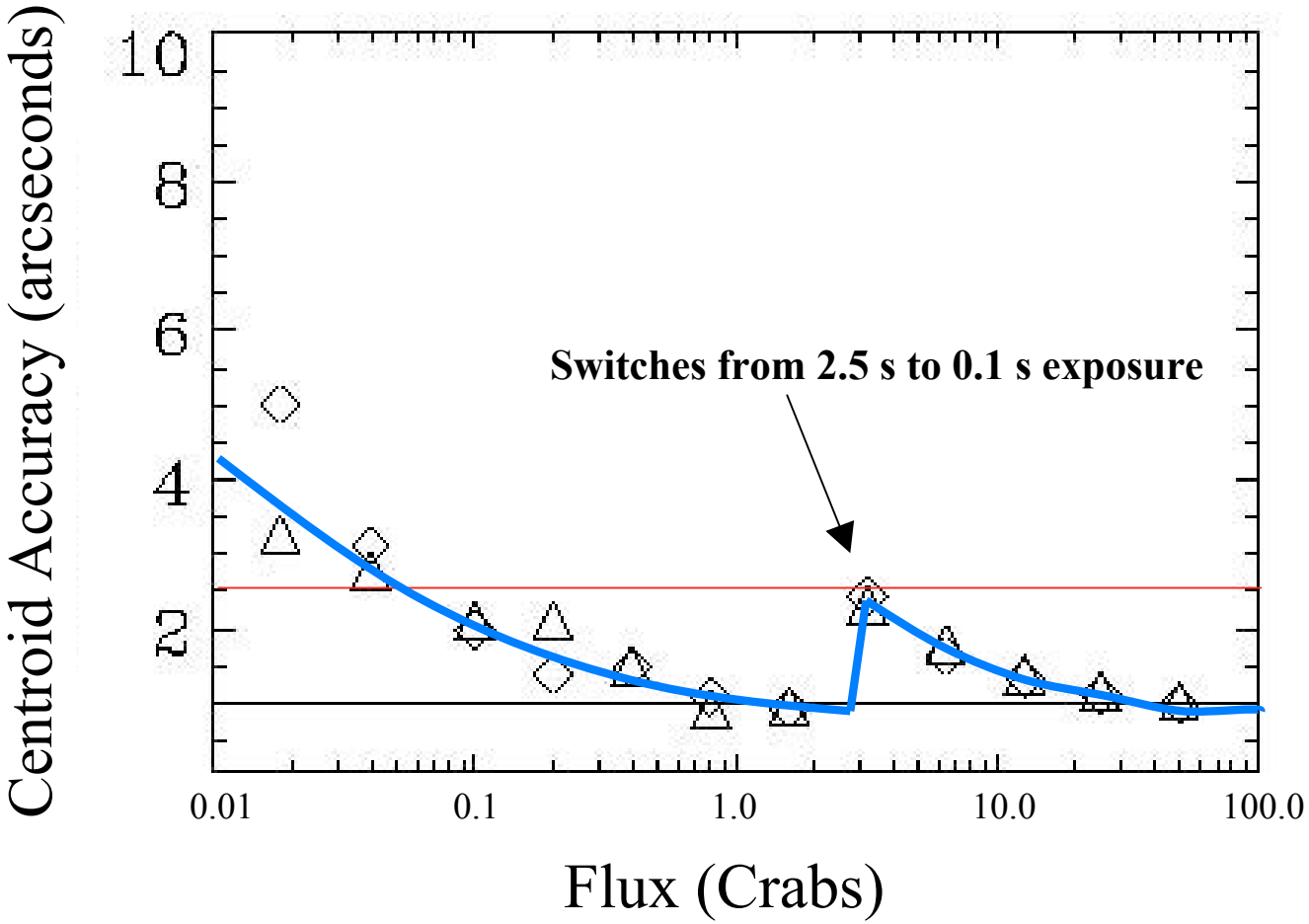



PSF is uniform over FOV
HPD = 18 arcsec @ 1.5 keV
= 22 arcsec @ 8.1 keV



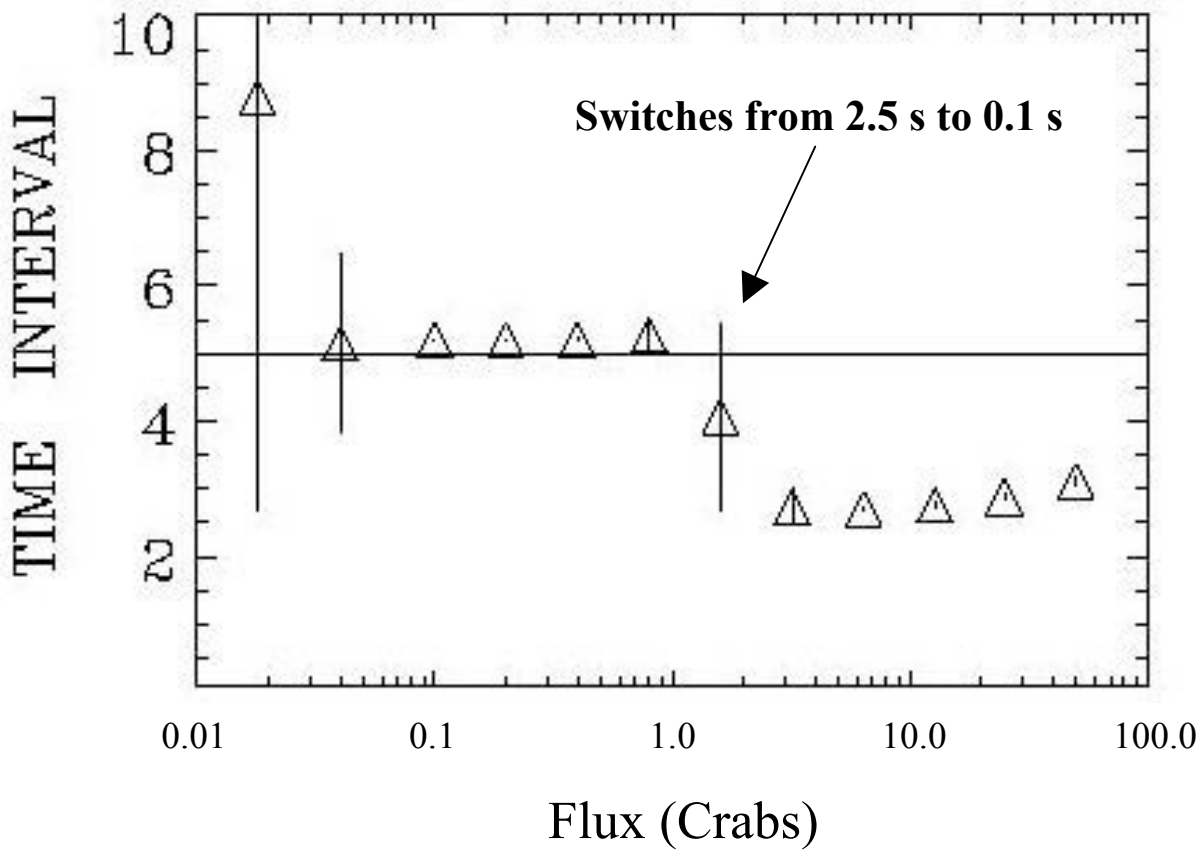
# XRT Position Determination Accuracy

**Panter test results: Centroid Accuracy vs Flux**

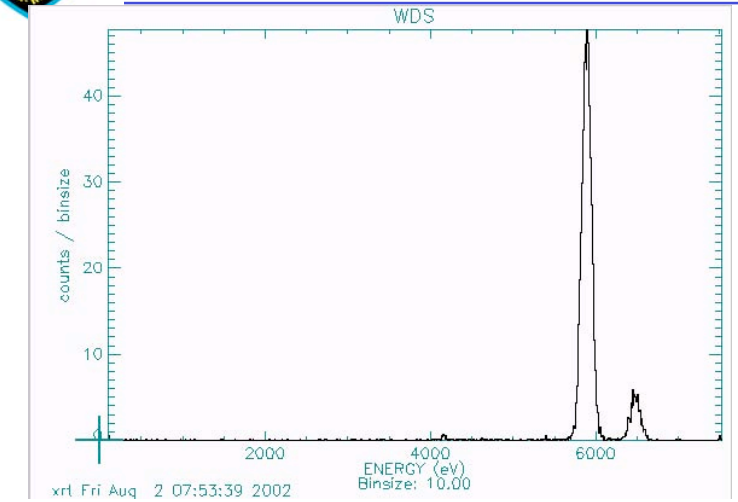


# XRT Position Determination Timing

**Total time (exposure + readout + calculation) < 5.2 s**

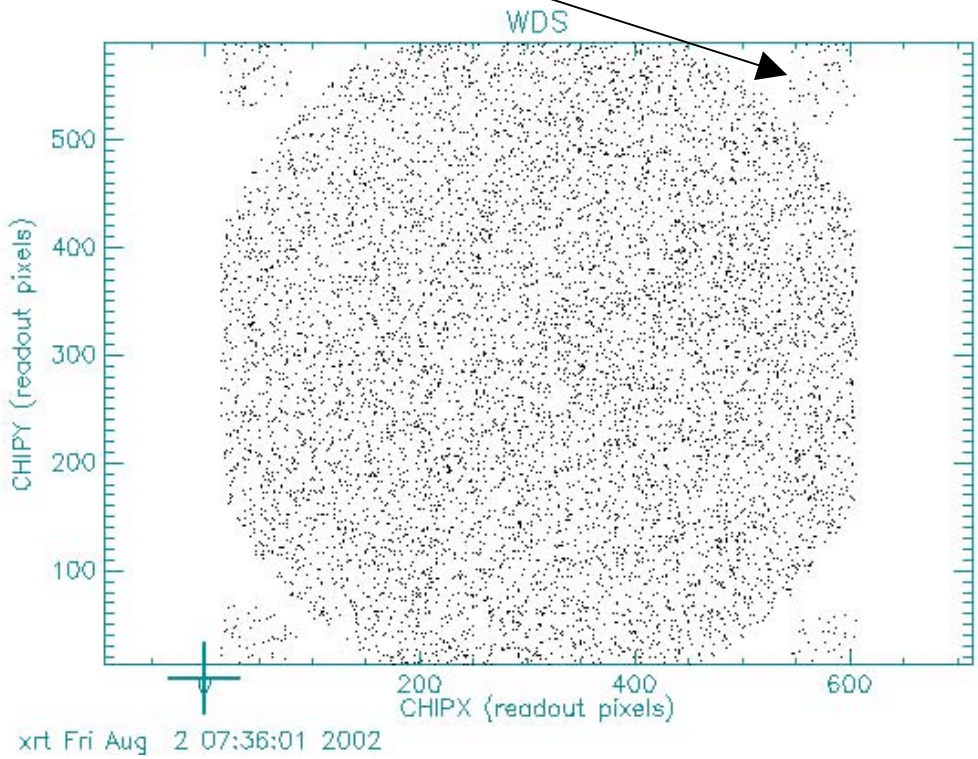


# XRT Spectroscopy




$^{55}$Fe spectrum (Mn Kα and Kβ lines at 5.89 and 6.40 keV) measured during XRT thermal balance tests.

XRT monitors these lines in the corners of the CCD image continuously.




Preliminary Energy Resolution (5.9 keV, Panter)
(requirement is < 150 eV at launch)

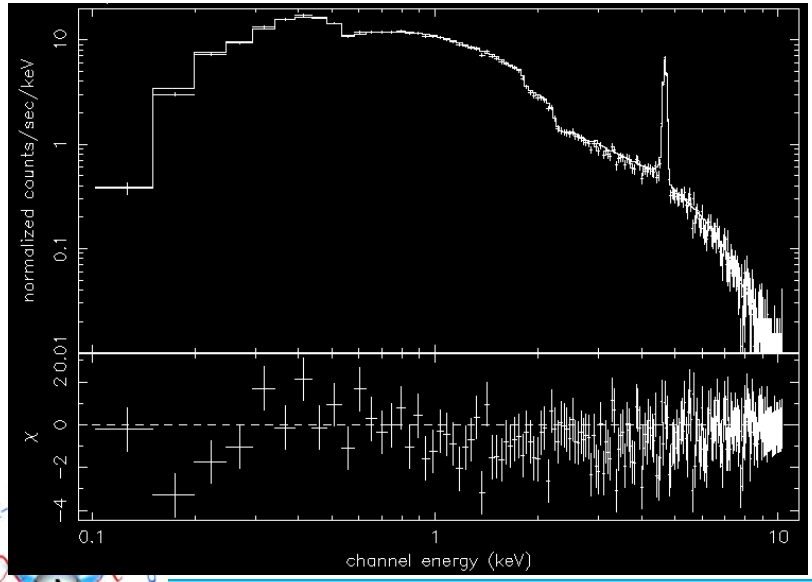
| Readout Mode | Energy Resolution |
|---|---|
| Imaging | N/A |
| Photodiode | 140 eV |
| Windowed Timing | 138 eV |
| Photon-Counting | 133 eV |

# XRT Spectroscopy

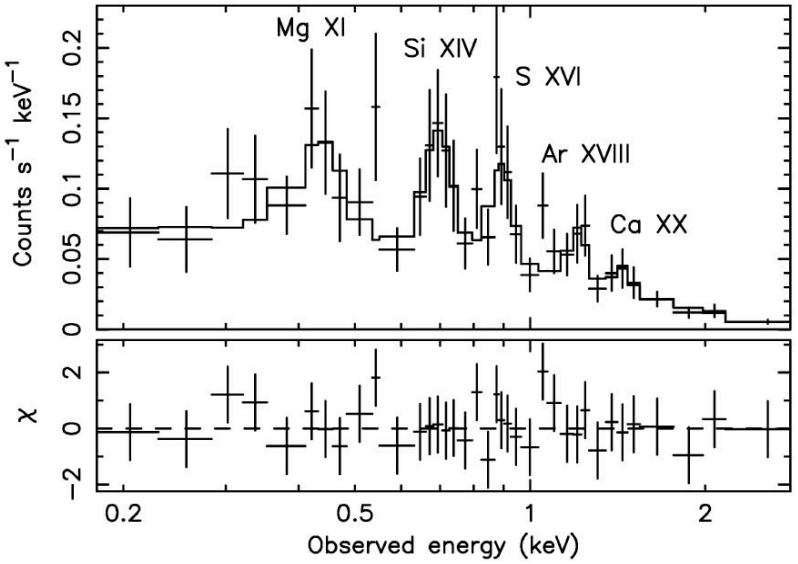
- X-ray spectroscopy of GRBs and afterglows
  - Redshift determination, ISM measurements

Energy resolution < 140 eV @ 5.9 keV

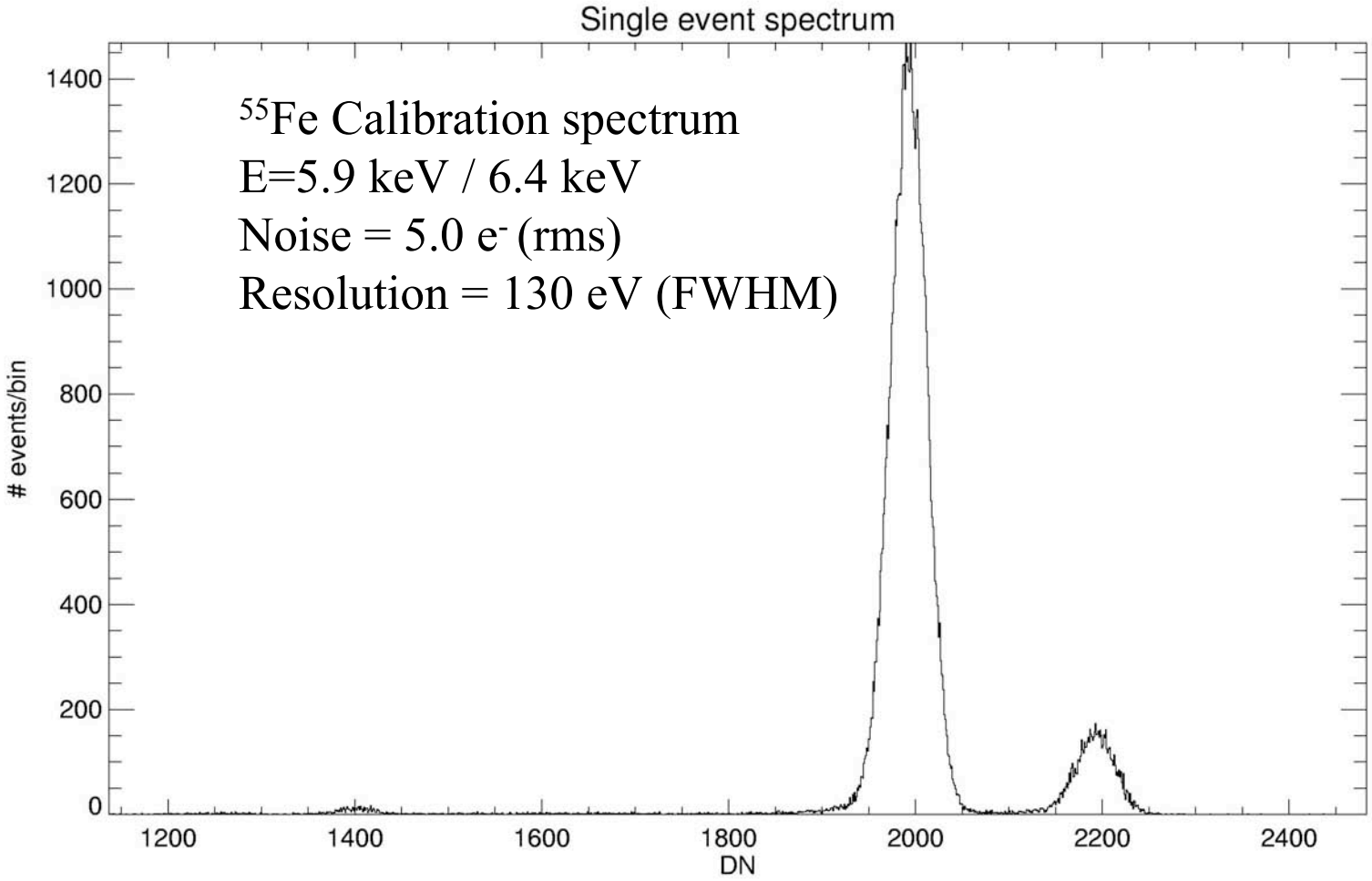
Simulated 1 hr observation of a GRB afterglow, 1.5 hours after the burst. Based on Beppo-SAX observation of GRB000214.




XMM observation of 5 ks from the afterglow of GRB011211, beginning 11 hours after the burst.



# XRT Calibration Spectrum




$^{55}$Fe Calibration spectrum
E=5.9 keV / 6.4 keV
Noise = 5.0 $e^-$ (rms)
Resolution = 130 eV (FWHM)

# XRT Data Products

- Prompt GRB data transmitted through TDRSS and distributed via GCN
- Full data sets transmitted through Malindi ground-station
  - Converted to standard OGIP FITS formats by Swift Data Center at NASA/GSFC
  - Data products available on SDC Quick-Look site within 2 hours of ground pass
  - XRT Data Analysis Software (ASDC) performs high-level processing and analysis (see talk by Tagliaferri)

# Summary

- XRT is a powerful, flexible instrument that will provide rapid, arcsecond GRB positions and spectroscopy
- Ground calibrations will be validated on-orbit using standard X-ray calibration sources
- GRB prompt data products converted to standard FITS formats and distributed in minutes via GCN
- Data products converted to standard FITS binary table formats and publicly available to community within hours